

COMMONWEALTH OF MASSACHUSETTS
Department of Telecommunications and Energy

RESPONSE OF THE ATTORNEY GENERAL TO DEPARTMENT OF
TELECOMMUNICATIONS AND ENERGY INFORMATION REQUEST
D.T.E. 05-27

Dated: August 5, 2005

Responsible Party: Jon Cavallo

RR-DTE-117 Provide literature concerning “the bathtub curve” (see Transcript, Vol. 17, p. 2753, lines 10-11).

Response: The “bathtub curve” referred to by Mr. Cavallo during his cross examination is a method for describing the lifetime of a population of products, such as sections of a gas distribution system. *See* attachment 8 for study of its application to a gas distribution system. The “bathtub curve” is actually a composite of three separate curves:

- A. An early “infant mortality” section of the overall curve, which describes the rapidly decreasing failure/failure rate resulting from material or construction defects,
- B. The e intermediate, horizontal section of the curve, commonly called “normal life” or “useful life,” during which infrequent and random failures occur, and,
- C. The “end of life” last section of the curve, which exhibits the rapidly increasing failure / failure rate resulting from the materials of construction reaching the end of their useful life.

The mathematical basis for sections (A) and (C) of the curve is work performed by Dr. E.H. Waloddi Weibull (1887-1979). Often referred to as the Weibull distribution, this statistical model is by far the most popular statistical model for life data in the world today. It is used in many applications, including gas distribution pipeline reliability forecasting. Documents (8) and (9) enclosed herewith exemplify typical uses of reliability analysis applied to natural gas distribution systems.

The following literature concerning the “bathtub curve” and the use of statistical reliability analysis are attached to this response: [BULK]

- 1. A biography of Dr. E.H. Waloddi Weibull, by Dr. Robert B. Abernathy.
- 2. “System Evolution And Reliability Of Systems”, Bathtub Curve Formulas.
- 3. “The Bathtub Curve and Product Behavior / Part One – The Bathtub Curve, Infant Mortality and Burn-in” Hot Wire, Issue 21, November 2002.
- 4. “The Bathtub Curve and Product Behavior / Part Two – Normal Life and Wear-Out” Hot

Wire, Issue 22, December 2002.

5. "Blueprint for a Comprehensive Reliability Program," ReliaSoft Corporation R&D Reports, February 3, 2003.
6. "The Bath Tub Curve," Power Re-View, Volume 1, Issue 3, October 2001.
7. "Bathtub Curve," Engineering Statistics Handbook.
8. "Project For Reliability: An Application To Natural Gas Pipelines," Acries Dias, Federal University of Santa Clara..
9. "Corrosion Assessment of an Army Installation Gas Distribution System Using MicroGPIPER" US Army Corps Of Engineers, USA CERL Technical Report FM-93/07 (January 1993).
10. MicroGPIPER Implementation Guide," US Army Corps Of Engineers, USA CERL Technical Report FM-92/04 (July 1992).